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**An evaluation of factors affecting show jumping warm-up on subsequent show
jumping performance in 1.30m class**

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Abstract:

Show jumping causes physical and physiological stress on horses' musculoskeletal structures, which can lead to decreased performance and injury. Appropriate warm-ups can enhance performance, decrease injury risk, as well as increase oxygen kinetics for better efficiency. Despite this, little is known for how warm-up routines affect show jumping performance. Forty-five warm-up routines of show jumpers preparing to enter the show ring were recorded and analysed. Kruskal Wallis analyses with post-hoc Mann Whitney U tests identified if the number of classes combinations competed, types of jumps attempted, warm-up duration, and time spent in each gait during the warm-up varied with rider and horse sex and age, and faults. Spearman correlations assessed if relationships occurred between warm-up duration and content, and the number of faults in the show ring, and horse age. Warm-up ranged from 3:51 to 62:46 minutes (median 15:09 minutes) and included at least two jumps (range 2 - 15). Walk was the most common gait, while upright fences were jumped the most. Knocking down or refusing a fence when warming up did not affect performance. Male riders jumped uprights twice as much as female riders ($p < 0.03$) but this did not impact their performances. Jumping a class prior to the 1.30 affected warm-up, competitors spent longer on the flat before jumping in they had competed earlier in the day ($p < 0.05$) and had fewer jump attempts if they had competed in the class just prior to the 1.30m ($P < 0.007$). Even though no significant differences were detected, combinations which accumulated > 8 faults spent less time warming-up. These results suggest warm-up tactics, riders and horses' age and sex did not influence significantly fault accumulation in the show ring, however warm up routines were influenced by rider decision making and horse age.

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Keywords: warm-up, success, jumping, horse, competition, equestrian sport

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No conflicts of interest relate to this work.

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Introduction

Show jumping appears to be the most popular equestrian sport within the three Olympic disciplines with higher competitor numbers than in the other disciplines (Gorecka-Bruzda et al., 2015). The goal of a show jumping competition is for horse and rider combinations of mixed age and gender to complete a course of obstacles. In order to be successful, they must complete the course without scoring any penalties or faults. Faults are accrued for knocking down or refusing a fence, or taking longer to finish than the allocated time. In the UK, show jumping courses consists of at least seven fences of variable height and technicality depends on the competition level (British Show jumping, 2016).

Technical skills, experience, power, speed and endurance are required from both the horse and rider to compete successfully in show jumping (Ferraz, 2010; McBride et al., 2012; Peeters, 2013). Success in show-jumping competition is therefore affected by the physical ability, fitness level, training level and behavioural responses of the horse to the show environment (Jastrzebska et al., 2017; McGreevy and McLean, 2007, Munster 2014). Rider performance is also a critical component of success: rider fitness, personality, skill and decision-making will dictate how horses are ridden around the course and will decide speed, stride patterns and approaches to the fences (Douglas et al., 2012; Rovere et al., 2016; Williams, 2017; Wolframm et al., 2008). Finally, the partnership between individual horse and rider dyads, and how well these partnerships work together, will influence performance (Williams, 2013).

Physical demands of competition

During a show jumping course, both the aerobic and anaerobic metabolism will be required for the horse to perform successfully (Williams, 2013). These parameters will be affected by the training methods as well as the natural capacity and fitness level of the horse and will directly affect performance (Munster, 2014; Williams, 2013). During a show jumping round the heart rate, packed cell volume, lactic acid and plasma cortisol level of the horse increase significantly, while the blood glucose level decrease significantly (Lekeux et al., 1991). The increase in heart rate is correlated to the increase of blood lactate level one-minute post jumping which is itself associated with muscle soreness and spasms (Harris et al, 2014; Roberts et al., 2014). When horses were jumped twice on the same day, muscle soreness and spasms have been linked to a decrease of performance (Roberts et al., 2014).

Levels of creatine kinase (ck) and aspartate aminotransferase (ast) also show an increase immediately after jumping and up to 24 hours post jumping (Gundasheva, 2016). These enzymes increase due to the increase of free radicals from oxidation and are believed to be linked to muscle soreness and damage (Jahn et al, 2001; Teixeira-Neto et al. 2008). An efficient warm-up increases the use of the aerobic metabolic pathway leading to a lower heart rate and respiratory rate, diminishing glucose expenditure as well as reducing lactic acid accumulation in a horse's muscles, reducing the onset of fatigue (Jansson, 2005; Mukai et al, 2008; Mukai et al, 2010).

In order to perform to their maximal capacity, the equine athlete should also be free from pain and injury (Dyson et al., 2018, Williams, 2017). In show jumping, the requirement to complete numerous jumping efforts in competition exposes the horse to increased ground reaction forces (GRF) and loading in the trailing forelimb (> 180%

88 increase in GRF) and hindlimbs (> 130% increase in GRF) during take-off, and a
89 further 200% increase in the forelimbs on landing (Hernlund et al, 2013). The resultant
90 repetitive stress and high concussion forces associated with jumping can potentially
91 cause damage to the distal limbs (Dyson et al., 2002; Herlund et al., 2013; Parkes et
92 al., 2012). Injuries to horses result in days lost from training as well as incurring a
93 financial loss (Egeval, 2013). Minimizing injury risk should therefore be a priority.
94 Research in human sports has shown that certain types of warm-up can reduce the risk
95 of injury as well as improve performance (Safran, 1989; Olsen, 2005; McGowan et al.,
96 2015). The term warm-up in sport is defined as a period of preparatory exercise in
97 order to enhance subsequent competition or training performance (Hedrick, 1992).
98 Three different factors are recommended for human exercise warm-up routines: 1) a
99 period of aerobic exercise to increase body temperature; 2) a period of sport-specific
100 stretching to stretch the muscles to be used in the subsequent performance; 3) a period
101 of activity incorporating movements similar to those to be used in the subsequent
102 performance (Altavilla, 2018). It is recommended there should be no longer than a 15
103 minutes break between the warm-up and the main competition. For human athletes if
104 a break occurs post warm-up then 2 minutes of active re-warm-up, a short jog and few
105 jumps should be sufficient to gain maximum benefits from the warm-up (Silva, 2018).
106 Whether the warm-up is passive (raising muscle or core temperature) or active
107 (involving exercise), the main goal is to increase body temperature which will increase
108 muscle temperature, increasing blood flow and oxygen intake by the muscles. A higher
109 body temperature will also increase the sensitivity of nerve receptors as well as the
110 speed of nervous impulse (Shellock, 1985; Kenney et al, 2011), enhancing
111 performance potential.

112 Different types of warm-up such as active versus passive and low versus high intensity
113 exist for human athletes and depending on the final goal, the warm-up type used should
114 vary for optimal performance in different disciplines (Bishop, 2003; Faigenbaum,
115 2005; McGowan et al., 2015). Similarly, different types of warm-up routines can
116 influence the performance of the equine athlete depending on the final goal, breed and
117 discipline of the horse (Jansson, 2005; Murray et al., 2006). In human subjects, an
118 active warm-up consisting of running 15 minutes at 60 or 70% Vo_{2max} has been shown
119 to increase anaerobic performance compared to no warm-up or a warm-up at 80%
120 Vo_{2max} (Stewart, 1998). Similar factors have been observed during the warm-up of
121 dressage horses prior to a competition where horses were walked, trotted and cantered
122 before practicing the skills and movement required in their dressage test (Murray,
123 2006).

124

125

126 Role of the warm-up in show jumping

127 Different studies have shown that the warm-up duration of show jumpers varies from
128 5-10 minutes (Dyson, 2018) to 12-27 minutes (Tranquille et al, 2014). The content and
129 duration of the warm-up appears to depend on the experience level of the rider as well
130 as on the competition level (Murray et al, 2006; Whitaker et al, 2008). Elite dressage
131 riders were shown to warm-up longer than novice riders prior to a dressage test and
132 the time spent in each gait varies depending on the level (Murray, 2006). Elite show
133 jumpers have been observed to warm-up asymmetrically, spending more time in the
134 left canter and jumping on average 13 fences prior to entering the show ring

(Tranquille, 2014 et al; Tranquille et al., 2009). Implementing an effective warm-up regimen to prepare for specific show jumping classes could improve performance and reduce the number of days lost to training due to injuries (Dyson, 2018; Egenvaal et al, 2013; Harris et al., 2014). Despite this limited research has evaluated the effect of warm-up characteristics on performance in show jumping, therefore the aim of the current study was to investigate if the warm-up routines of show jumpers competing in a 1.30m class influenced their competition performance measured by fault accumulation.

Materials and methods

The warm-ups of all competitors preparing to compete in a British Show Jumping 1.30m class in a competition centre in the South West of England were recorded using video cameras. The study took place over two different affiliated British Show jumping events, fifteen days apart including three 1.30m classes. Class A took place during the first competition and Class B and C were both events within the second competition which took place on two successive days. These classes were selected for data collection in order to limit as much as possible the potential confounding effect of rider and horse experience disrupting the data (Peeters, 2013). In the first show (class A), drawn order was not used, participants could come in the warm-up arena and put a number on the board which would define their drawn order. At the second show (Class B and Class C), drawn order was used so riders were allocated a time slot to be ready to enter the ring. Ethical approval for the study was granted by the Hartpury University Ethics Committee. Permission to record the riders during their warm up was granted by the show organizers and participating riders.

Four video cameras were set up in the arenas and used to record the warm-up of all participants in Class A, B and C. Horse and rider combinations used two arenas to warm-up prior to jumping the class in a third arena (show ring) (Figure 1). For all three classes, the warm occurred exactly in the same manner. Initially, horses were warmed up in an indoor arena (MA) of 60m by 25m with a synthetic Andrews Bowen surface (Andrew Bowens Ltd, Singleton, United Kingdom). Riders had free access to a single upright and a single oxer fence. A maximum of 12 horse and rider combinations were allowed into this arena at any one time, and there were no restrictions on when combinations began their warm-up in relation of the drawn order for jumping. Approximately 5 minutes before the scheduled order, combinations were called into the collected ring (CR) (25m by 35m, Andrews Bowen surface) situated alongside and connected to the show arena. To access the CR, riders had to cross the lorry parking and follow a downward track approximately 150m long. Within the CR, riders again had access to an upright or oxer fence and were allowed to jump them as many times as they wished until they were called into the show ring.

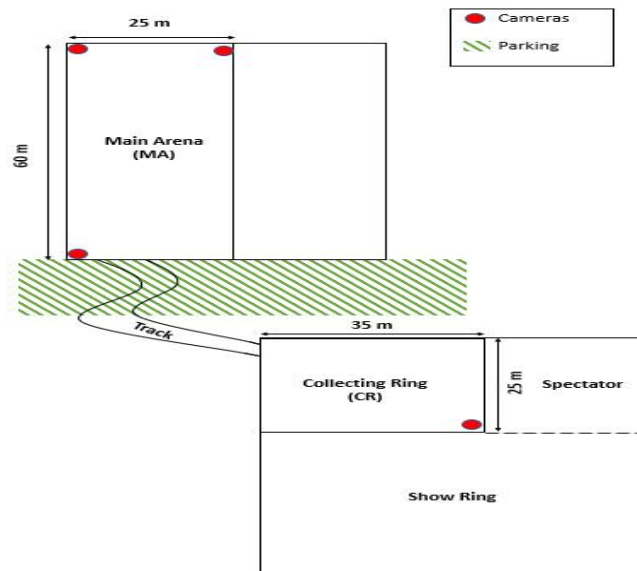


Figure 1: Set up of the infrastructures and the cameras for the study

Experimental set up

Four video cameras (three cameras Sony HDR-CX405; one Sony HDR-CX330E; one Sony HDR-CX190E; one Sony DCR SR15; 60 frames per second) recorded warm-up routines. The use of video cameras minimized human error and allowed data to be collected from the two warm-up arenas used simultaneously (Pierard, 2015). Concurrently a single experienced observer was stationed at the entrance of the main warm-up arena (MA) and noted the name of the riders, colour of their horses and tack used. This enabled horse and rider combinations to be recognized on the camera when the warm-up routine were analysed. Three cameras were installed in three corners of MA to prevent blind spots when videoing; one camera was located in the back-right corner of CR where the gate of CR and the fence were clearly visible. (Powers, 2005). All the cameras were set on tripods and located behind a barrier to avoid any incident with the horses (Pierard, 2015). Footage was recorded simultaneously from all cameras once riders entered the MA to commence their warm-up or the CR to continue their warm-up. To enable the height of jumping efforts used during the warm-up to be calculated during data analysis, reference markers were positioned on the fence wings at a height of 1m (blue tape) and at 1.20m (yellow) in both MA and CR.

Horse and rider combination selection

Rider sex and horses' age and sex were also recorded from the competition entries. The identity of horse and rider combinations and the time they entered the MA and the CR were noted by an observer. All combinations were video-recorded for the duration of the warm-up to enable subsequent footage from eligible horse and rider combinations to be analysed. To be included in the study, combinations had to warm-up in the MA with no break (e.g. no exiting MA and then coming back in a few minutes later) only leaving the MA when they were called to the CR by the stewards and going directly there. Horses also had to be ridden during the warm-up by the riders competing them in the show ring in order to avoid extra external factors affecting the data. Horses that expressed nervous or conflict behaviours were automatically excluded from the study to limit external factors affecting the results (Gorecka-Bruzda,

2015). A total of forty-five warm-up routines were eligible for observation across 27 horse and rider combinations.

Video analysis

For the twenty-seven combinations that met the inclusion criteria, the warm up for each horse and rider dyad was studied individually. From the video footage recorded, a consistent analyst noted the amount of time horses were ridden in each gait in the MA including walk, trot and canter periods, as well as the duration combinations stood still or were hand walked during the warm-up. The total time spent in each gait, total duration of the warm up and time spent working on the flat before jumping in the MA were calculated using Microsoft Excel Version 2010. Practice fence type was defined as: cross poles (any height), upright lower than 1m (U<1), upright between 1 and 1.20m (U1-1.20), upright above 1.20m (U>1.20), oxer lower than 1m (O<1), oxer between 1m and 1.20m (O1-1.20) and oxer over 1.20m (O>1.20), height (m) and number of jumps completed, as well as the time the dyad started jumping were also recorded. If the horse knocked a pole or refused a fence, it was recorded as a jumping fail. In CR, the number of jumps, height and type of fence were recorded and analysed.

To enable the impact of jumping a preceding class on the same day of competition, horse and rider combinations who had competed the class just preceding the 1.30m were identified as Group 1, those who had competed two classes prior to the 1.30m were placed in Group 2 and those who only competed in the 1.30m class made up Group 3. The competitive performance of horse and rider combinations during the 1.30m competition first round was recorded as the number of faults incurred.

Data analysis

The mean and standard deviation (sd) of warm-up routines length for each class were calculated using Statistical Package for the Social Science (IBM SPSS computer software version 22).

Data did not meet the assumptions of normality, therefore non-parametric analyses were used to assess if differences occurred between warm-up regimes (Field, 2013; Murray, 2006). A series of Kruskal Wallis analyses with post-hoc Mann Whitney U tests identified if differences occurred in the warm-up regimes: jumping effort type and duration in walk, trot and canter related to rider gender and age, horse sex and age, number of classes combinations were competing in prior to the 1.30m class, and success (faults in competition) (Somer, 2015). Spearman correlations determined if relationships existed between warm-up total duration and horse age. Significance was set at $P < 0.05$.

Results

Forty-five warm-up regimes were evaluated across 27 riders and 29 horses (Table 1). Fifty six percent ($n = 15$) of riders were male and 44% ($n = 12$) were female. Out of the 29 horses, 20 (69%) were geldings, 6 (21%) were mares and 3 (10%) were stallions. 14 warm-up routines were assessed for Class A, 16 for class B and 15 for class C.

Table 1: Number of horse and riders who participated in the study (WU: warm up; class A; class B and class C)

Rider	Number of warm-ups	Number of horses	Classes competed in
1	3	1	A, B, C
2	2	1	A,B
3	4	2	A, B, B,C
4	2	1	A,B
5	3	1	A,B,C
6	3	2	B,C,C
7	2	1	B,C
8	2	1	B,C
9	2	1	B,C
10	2	1	B,C
11	2	1	B,C
12	2	1	B,C
13	2	1	B,C
14	1	1	A
15	1	1	A
16	1	1	A
17	1	1	A
18	1	1	C
19	1	1	A
20	1	1	A
21	1	1	A
22	1	1	A
23	1	1	C
24	1	1	B
25	1	1	C
26	1	1	C
27	1	1	B

Warm-up regimes

Warm-up regimes varied greatly amongst all riders studied in MA, ranging between 3:51 to 62:46 minutes with a median duration of 15:09 minutes and mean of 18:43±12:24 minutes as observed in figure 2. Twenty-two and ten riders warmed up for shorter than 15 and 10 minutes respectively. Time spent on the flat before jumping varied across riders with a range of 2:39 minutes to 58.34 minutes and a mean of 12:19±11:18 minutes (median 9:33 minutes). For 55.6% (n = 25) time spent on the flat before jumping was less than ten minutes. During the warm up, walk was the most prevalent gait used ranging from 3:48 minutes to 25:37 minutes (median 5:48 minutes) and trot was the least used ranging from 0 to 8:39 minutes (median 2:19 minutes)

Influence of warm-up on show jumping performance

(Figure 3). The duration of walk and trot was not proportional and varied between each rider. For 62.2 % of the riders, trot duration was less than 3 minutes during their entire warm-up. The use of canter ranged from 1:15 minutes to 10:06 minutes (median 5:09 minutes). Over the 45 warm-up routines studied, 67 % riders (n = 30) stood still for 10 seconds or more, including 27 % of the riders (n = 12) who stood still for less than a minute (range 0 to 37:08 minutes). In class A, 64 % of the riders (n = 9) stood still (median 0:40 minutes), in class B 62 % of the riders (n = 10) stood still (median 1:37 minutes), in class C 73% of the riders (n = 11) stood still (median 1:19 minutes).

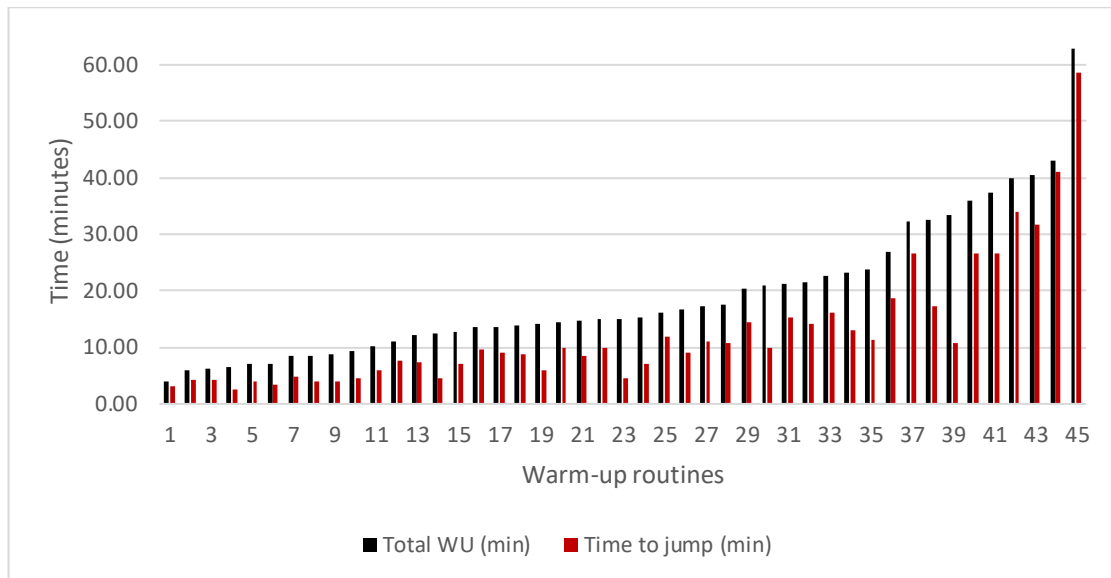


Figure 2: Warm-up durations and time spent on the flat for the forty-five combinations studied in the main arena; mins: minutes

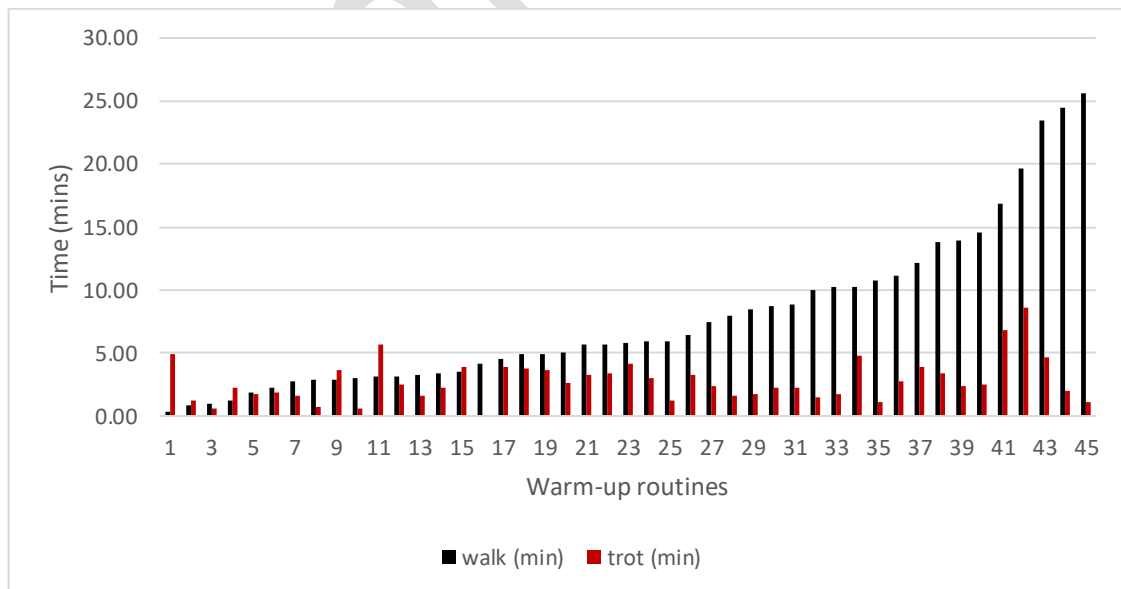


Figure 3: Time spent in walk and trot for each rider studied; min: minutes

On average riders attempted 9 fences before entering the show ring (range: 2 to 15). Cross poles were the fences used the least during the warm up in both MA and CR over the three show jumping classes, with only 23.1 %, 18.7 % and 25 % of the riders using them in class A, B and C, respectively. Uprights between 1 - 1.20m were used

by all riders observed in all three classes. The number of jump fails were higher for participants of class B and C (18.8 %, 18.8 %) compared to class A (7.7%).

All combinations jumped a minimum of two warm-up fences in MA, with the total number of fences ranging between 2 and 14 fences per rider. Typically, combinations elected to jump uprights between 1 - 12.0 m and above 1.20 m followed by oxers between 1 - 1.20 m in the MA warm-up. Over the three classes studied, 352 jumps were attempted in MA, 15 cross poles, 182 uprights and 156 oxers all heights were included, out of which only 9 attempts were fails.

Seven percent (n = 3) of horse and rider combinations completed no further jump attempts in CR (40 %: 1 jumping efforts; 37.8 %: 2 jumping efforts; 15.5 %: 3 jumping efforts). In CR, uprights above 1.20 m were the type of fence most attempted (68.9 %; n = 31), with a total of 56 uprights of various heights jumped compared to only 17 oxers of varied heights, with no cross poles jumped. Out of the 73 fences attempted in CR, only 3 attempts resulted in jump fails.

Across both warm-up arenas, uprights above 1.20 m were the fences most often used (n = 96) followed by uprights between 1 - 1.20m (n = 76). Overall, combinations completed a minimum of two jumping attempts, range: 2 to 15 jumps (median: 8), with 9 and 10 jumping efforts being the most common approach observed (17.8 % each). Out of the 425 attempts, all jumps mixed, 12 fails were recorded (2.82 %).

The impact of the rider

Out of the 27 riders studied, two took part in the three classes with the same horse, 11 riders took part in two classes with the same horse and one rider took part in 2 different classes with two different horses. As observed in table 2, duration of the warm-up, time to jump, time spent standing, walking, trotting and cantering varied between riders on different days. Differences between warm up routines of the same rider on different days ranged from 59 seconds to 29 minutes 29 seconds with 50 % (n = 7) having ten minutes or more difference in the total warm-up duration. The number of attempts on fences varied for 78.6 % (n = 11) of the riders ranging from 1 to 6 fences.

Table two: Range of warm up duration, time to jump, stand, walk, trot, canter and range of attempts number; min: minutes

Influence of warm-up on show jumping performance

Rider	Range total WU (min)	Range time to jump (min)	Range stand (min)	Range walk (min)	Range trot (min)	Range canter (min)	Range of total number of fences attempted
Rider 1	12:36 to 40:25	4:35 to 31:45	0 to 19:19	3:17 to 11:08	1:40 to 3:55	7:24 to 7:43	9 to 15
Rider 2	43:05 to 62:47	41 to 58:34	21:04 to 37:08	0:48 to 13:50	3:21 to 4:10	3:48 to 10:06	10 to 13
Rider 3a	3:51 to 7:07	3:05 to 3:27	0	1:02 to 1:54	0:39 to 1:41	1:57 to 3:34	5 to 9
Rider 3b	16:03 to 21:21	12:01 to 15:23	0:09 to 3:35	8:01 to 10:17	1:37 to 1:44	7:14 to 6:05	9 to 11
Rider 4	6:15 to 12:44	4:14 to 7:13	0	0:54 to 4:56	1:17 to 3:46	4:04 to 6:12	9 to 12
Rider 5	17:25 to 37:23	10:59 to 26:36	0:17 to 2:31	8:27 to 24:32	1:46 to 4:39	4:14 to 8:59	8 to 13
Rider 6	6:31 to 36 :00	2:39 to 26:42	0 to 44	3:04 to 19:35	0:34 to 8:39	2:53 to 6:02	5 to 10
Rider 7	14:11 to 32:20	5:51 to 26:42	3:23 to 13:37	3:24 to 6:28	2:15 to 3:17	6:08 to 8:41	8 to 11
Rider 8	12:34 to 15:24	8:59 to 7:04	0 to 0:24	3:05 to 8:45	2:13 to 05:37	3:52 to 6:46	8 to 9
Rider 9	16:36 to 17:35	7:07 to 9:08	0:25 to 1:2	5:41 to 10:42	1:03 to 3:23	4:24 to 6:18	10
Rider 10	15:09 to 33:24	4:37 to 10:38	0 to 3:20	7:29 to 25:38	1:09 to 2:20	3:17 to 5:30	9
Rider 11	26:56 to 40:01	18:36 to 34:00	2:39 to 8:17	12:09 to 16:51	3:54 to 6:47	5:06 to 6:54	11 to 12
Rider 12	12:17 to 15:24	7:04 to 7:29	0:09 to 0:24	5:52 to 8:45	2:13 to 3:00	2:10 to 3:42	7 to 9
Rider 13	14:11 to 23:45	5:51 to 11:28	3:23 to 7:53	3:24 to 10:02	1:31 to 2:15	4:59 to 6:08	8

Male riders were nearly twice as likely to jump their horses over oxers during the warm-up in the MA compared to female riders ($p = 0.03$; 48 % vs. 27 % respectively; Figure 4).

Influence of warm-up on show jumping performance

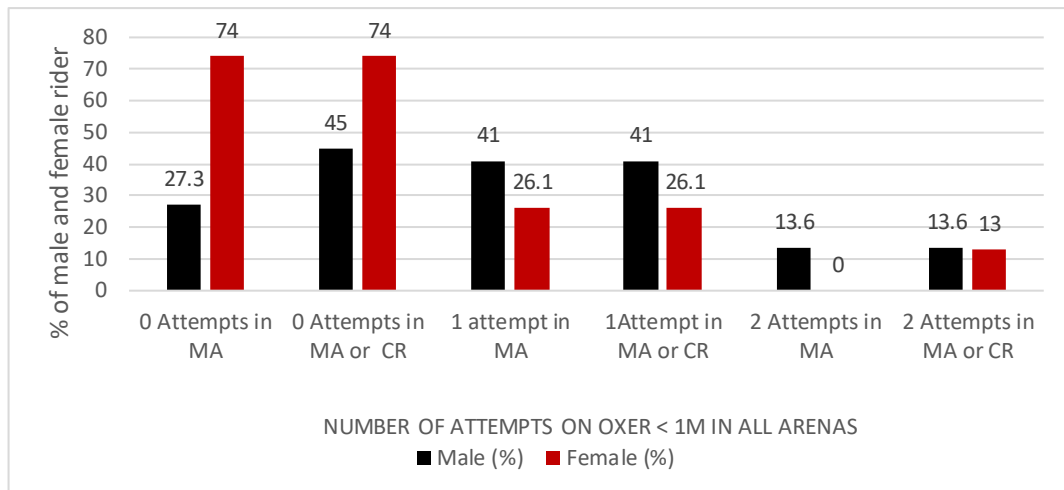


Figure 4: Number of attempts on oxers below 1m in main arena or collecting ring for male and female riders; MA: main arena; CR: collecting ring; %: percentage

Sex and age of the horse

Differences in warm-up regime were also observed related to horse sex and age (Figure 5), however these were only significant for the number of upright fences jumped < 1m ($p = 0.05$). Across MA and for MA and CR combined, geldings were jumped on average 1.5 attempts (median: 2 attempts) while mares and stallions had an average of 1.2 and 1.25 (median: 1 attempt). Both mares and stallions had no attempts over fences lower than 1m in CR. Riders who rode geldings always incorporated an upright fence in their warm-up.

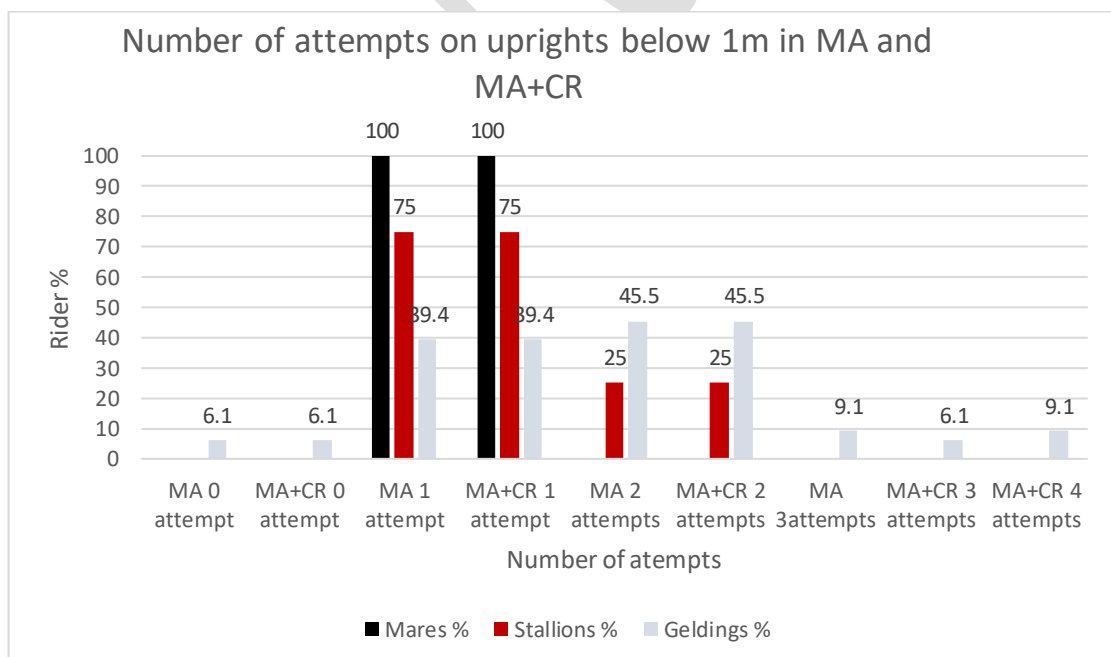


Figure 5: Number of attempts on uprights below 1m main arena, and main arena plus collecting ring for geldings, mares and stallions

Significant differences were found between horse age and time to jump ($p = 0.01$) as well as time spent in walk ($p = 0.03$) and trot ($p = 0.045$). As observed in figure 6, horses aged 9 years spent more time working on the flat (mean: 26:11 minutes;

Influence of warm-up on show jumping performance

median: 25:10 minutes) before jumping than other age groups. Horses aged 13 years spent more time in walk (mean: 15:32 minutes) while horses aged 14 years and over spent the least time in walk (less than 5 minutes).

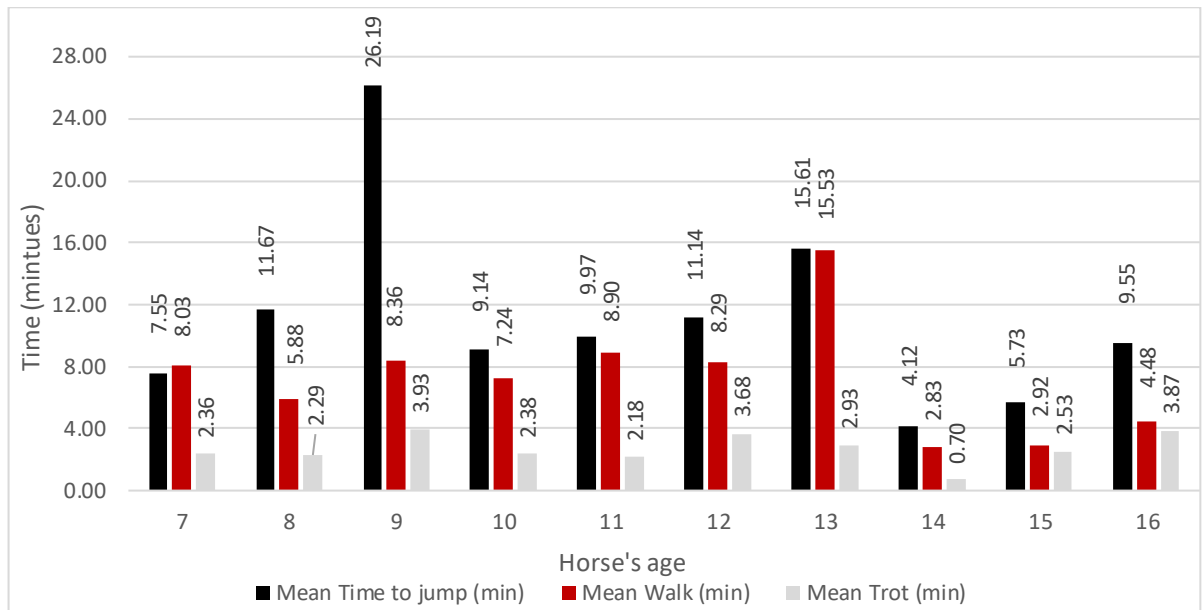


Figure 6: Mean time spent on the flat before jumping, in walk and trot depending on the age of the horses; min: minutes

Impact of competing in additional classes on warm-up regimes

The warm-up routines of Group 1 (horse and rider combinations who competed in the class prior to the 1.30 m class), Group 2 (horse and rider combinations who competed in a class earlier during the day) and Group 3 (horse and rider combinations who only competed in the 1.30 m class) differed (Figures 7 and 8). Total warm-up duration was longer for group 2 (median 32:43 minutes) than group 1 (median 8:20) and group 3 (15:10 minutes). Group 2 spent significantly more time warming up on the flat before jumping (median 28:34 minutes) compared to Group 1 (median 4:02 minutes; $p = 0.05$) and Group 3 (median 8:50 minutes; $p = 0.05$). This pattern was repeated for trot and canter, Group 1 ($p = 0.02$) and Group 3 ($p = 0.02$), and Group 1 ($p = 0.007$) and Group 3 ($p = 0.007$) respectively. No significant differences were found for the time spend in walk between the three groups ($p > 0.05$).

Influence of warm-up on show jumping performance

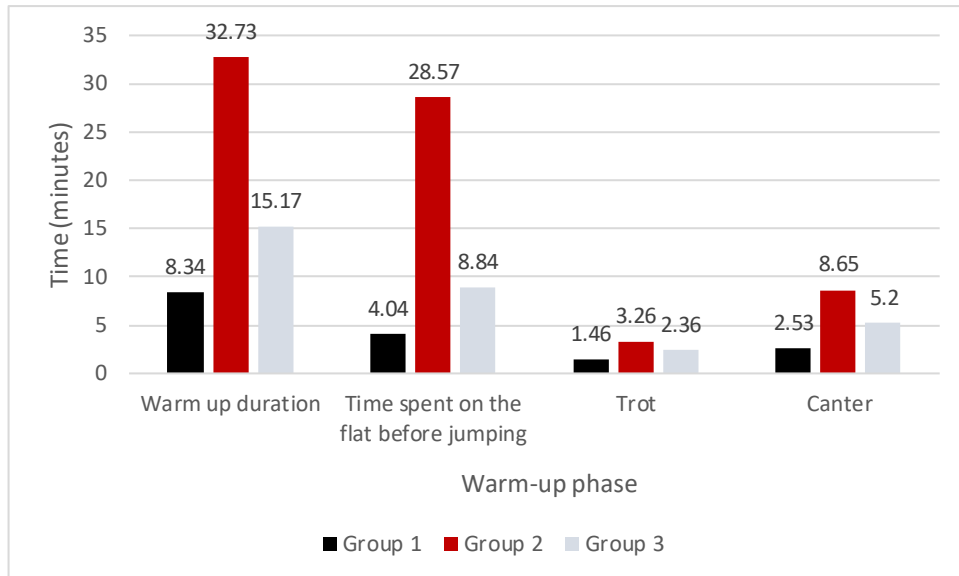


Figure 7 : Median of warm-up duration, time spent on the flat before jumping, trot and canter for riders having jumped a previous class or not.

As observed in figure 8, significant differences were also noted in the total number of jump attempts, with Group 2 and 3 recording more jump attempts than Group 1 ($p = 0.007$, increase of 42.9 %) and Group 3 had more attempts on vertical between 1-1.20 than Group 1 and 2 ($p = 0.007$, increase of 100 %).

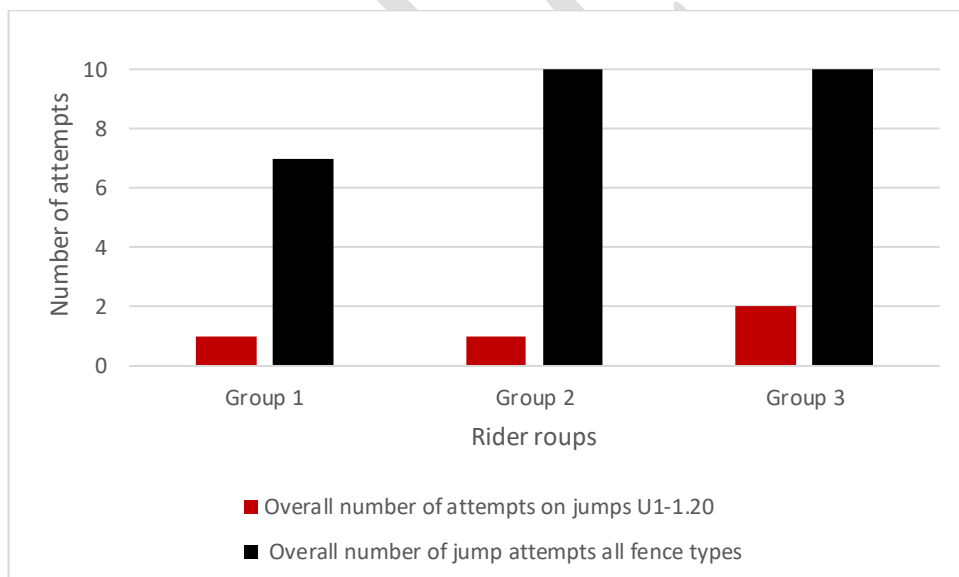


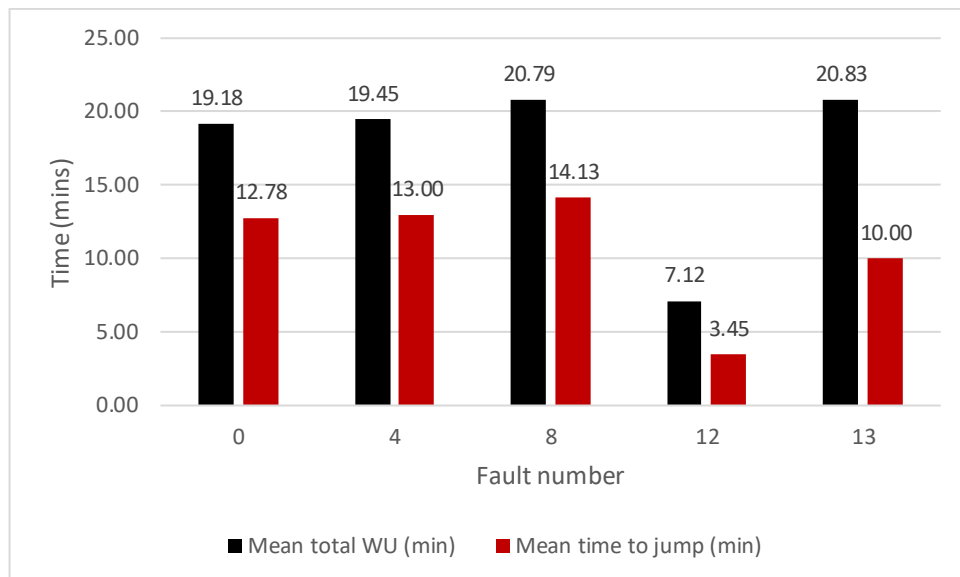
Figure 8 : Significant differences in jump attempts for group 1, 2 and 3

Warm-up routine and success in the ring

No significant differences were found between number of faults in the show ring and warm-up routines ($p > 0.05$). However as observed in figure 9, horse and rider combinations who acquired > 8 faults spent less time on the flat before jumping than competitors who recorded 8 or less faults.

Influence of warm-up on show jumping performance

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409 Figure 9: Warm-up routine duration and time spent on the flat before jumping
410 compared to faults acquired in the show ring. Min: minutes

411

412 No significant correlations were found between horse age and gender or faults scored
413 and any of the variables investigated ($p > 0.05$).

Discussion

The results demonstrate that while warm-up routines varied across individual horse and rider combinations, the format of the warm-up was not associated with performance measured as faults accrued in competition. In human studies, an active warm-up with a recovery phase has shown to increase athlete's performance when done appropriately for the task to be achieved (Bishop, 2003). A high-load dynamic warm-up enhances power and strength performance and it is essential to warm-up core temperature to increase oxygen intake, ATP turnover, muscle glycogen availability and increase motor unit recruitment (Herman, 2012; McCrary, 2014). In thoroughbreds, low, moderate or high intensity warm-up does not affect performance on a treadmill but affects how quickly core temperature increase and how quickly acid lactic reaches threshold (Mukai, 2010). In order to increase blood temperature, heart rate and lactic acid slowly and gradually, a low intensity warm-up should be used (Mukai, 2010). The walk should therefore be used to stretch the horse, and ready the body to work before using more dynamic gaits. Jumping also plays a key role during the warm-up as rehearsal of the skills about to be performed should be practiced to maximize readiness of the body, activate and recruit the muscles required (Altavilla, 2018; McCrary, 2014; Young, 1985).

Trot was the gait used the least during warm-up with standing, walking and cantering duration being higher than trot. Wakeling (2007) studied the effect of walk and trot on the longissimus dorsi, which is responsible for lateral bending, axial rotation and extension of the spine (Haussler, 1999). This muscle is important for show jumpers as lateral flexion and axial rotation of the spine occurs during a show jumping course. In Wakeling's study (2007), it was discovered that more activity was created in the longissimus dorsi at a trot than at a walk. Trot work also increases the horse's cardiovascular input, warms up muscles symmetrically, while minimizing energy expenditure, glycogen store depletion and lactic acid production (Lekeux, 1991). These studies suggest that trot provides a suitable gait to facilitate aerobic warm up for competition and should not be neglected.

During the warm-up 67% of the riders stood still for 10 secs or more. Recovery in human athletes has proven to be essential, to regulate body temperature, heart and respiratory rate. If a break of 15 mins is taken from the warm-up then a 2 mins active re-warm-up was necessary before the main performance. The fact that riders had to walk down the track to get to CR five mins before entering the show ring implemented a forced break into their warm-up routine. Once in holding they had about five mins for an active re-warm-up which has proven to be sufficient in human subjects (Silva, 2018).

In both humans and horses, a 15 mins warm-up has proven to increase performance however in this study 49% (n=22) warm-up for shorter than 15 mins, and no significant difference was found in performance (Murray, 2006; Stewart, 1998). On average, riders jumped 9 fences during the warm-up, which is lower than the average of 13 fences observed by Tranquille (2014). The lower number here could be related to a number of horse and rider combinations jumping in multiple classes, which could have influenced their decision making when deciding warm-up strategies. Future research

to understand what factors influence rider decision making when selecting warm-up tactics would be beneficial.

To restrict as much as possible the potential confounding effect of rider and horse experience disrupting the data the three classes studied were of the same level (Peeters, 2013). However, riders and horses' experiences in the show ring as well as the extent of their partnership can be limiting factors (Powers, 2005; Williams, 2013).

Rider sex did not affect horse performance in the ring, which is analogous with the results found by Meyer (2008) and Wolframm (2010). However, rider sex was related to differences in the warm-up routines observed. Female riders jumped less oxers than male riders of a lower height (below 1m), suggesting female riders preferred a more direct strategy to jump fences of increased heights during the warm-up.

Further research is required to understand if this result occurred by chance or reflects differences in decision making aligned to rider sex. Age of the horse did not affect performance in the ring, however the duration of the time spent on the flat, time spent in walk and trot during the warm-up varied in relation to horse age. Anecdotally riders consider older horses should walk longer during the warm-up than younger horses, however in this study, we found that horses aged 14 and over spent the least time in walk.

Warm-up routines were affected when a previous class was jumped prior to the 1.30m. Riders who had jumped the class just before the 1.30 spent less time warming up (median 8:20 minutes) compared to those who had jumped a class earlier in the day classes (Median 32:43 minutes). Longer warm-up undertaken by combinations which had jumped earlier in the day could be linked to Roberts et al. (2014) finding that horses jumping twice on the same day had an increase in lactate level associated with muscle soreness leading to a decrease in performance on the second round, however in this study no detrimental impact on performance was noted. Our results suggest warm-up routines in horse and rider combinations competing in 1.30m classes are more variable than elite level combinations. Tranquille (2014) reported average warm-up lengths of ~18 minutes in 10 elite showjumpers competing across a three-day world-class training event. In class C, when no participants jumped a previous class the time spent walking in the warm-up increased. However this could also be related to the fact that the class was early in the morning and that the temperature was lower, therefore horses may have required an increased time in walk to stretch and engage in a low intensity activity to increase their body and muscle temperature prior to working in collection or gymnastic jumping.

Limitations

Other parameters that could influence performance were not taken into account in this study. These included training details, the history of the horses, potential previous time off due to injury, horses' experience in the ring and at this show venue as well as transport duration (Sommer, 2015; Tateo, 2012; Valera, 2012). The tack used on the horses was also not assessed, ill fitted tack can create discomfort and reduce performance (Clayton et al, 2013). It was noted that before jumping in the warm-up or before entering the show ring, multiple riders equipped their horses with back boots, which could have been weighted or pinched boots which has proven to increase

performance (Murphy, 2009). The effect of pre-entry and drawn order were also not assessed in this study and can be considered a limiting factor on performance. Class A was a class that required no previous entry and therefore no drawn order was given prior to the class. On this day, standing duration was higher than on any other days. Each parameter studied were not independent of each other, and age and experience of the rider were not taken into account.

Conclusions

Warm-up routines varied in duration and gait used amongst riders competing in the same class. Warm-up structure and knocking down or refusing a fence during the warm-up did not affect the number of faults horses scored during 1.30m classes. Even though there was no significant difference detected, riders who scored > 8 faults spent less time on the flat before jumping during the warm-up. Rider sex influenced the content of the warm-up routine observed; warranting further research to explore the underlying factors which drive these differences. Horse age also influenced warm-up structure, with horses aged 14 and over spending less time in walk than younger horses. Jumping a class earlier in the day or just prior to the 1.30 affects warm-up routine duration and content. Warm-up routines also varied for the same horse/rider combinations competing in a 1.30 on different days. Trot was the gait the least used for warming-up, further research would be required to understand the long-term effects of such practices. The long-term effect of a short warm-up routine should be investigated since prior studies have proved the positive effect on the equine musculoskeletal structures which could decrease injury on a long term-basis. Further research of possible factors which could affect warm-up routines and competition performance such as drawn order, number of horses per rider in the class, time of the day and transport is warranted.

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